APPENDIX MS1. ASSESSING POTENTIAL CONFLICTS WITH WAVE ENERGY GENERATION ALONG THE OREGON COAST

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INTRODUCTION

The process of coastal and marine spatial planning (CMSP) encompasses a broad array of activities that can take place in and affect large marine ecosystems such as the California Current. Assessing potential conflicts and evaluating tradeoffs among the activities is an important part of CMSP. For example, the new U.S. Ocean Policy includes a mandate for coastal and marine spatial planning (CMSP or MSP) to "reduce conflicts among uses and between using and preserving the environment to sustain critical ecological, economic, and cultural services for this and future generations" (White House Council on Environmental Quality 2010).

In this section, we focus on one activity – the generation of wave energy – and how it might conflict with other existing activities in the context of CMSP. Wave energy has the potential to generate substantial amounts of renewable electricity and provides relatively continuous and predictable power, which is advantageous for electrical grid operation. Although the technology has yet to be put into commercial production, wave energy generation costs are likely to fall over time as the underlying technologies develop and the industry expands. Although much uncertainty exists, wave energy may become economically feasible in the near feature if fossil fuel energy costs continue to increase.

While waves can provide a source of clean and renewable energy, the facilities for capturing wave energy and producing electricity have a substantial footprint in the marine environment. For this reason, they can conflict with existing ocean uses or conservation strategies for protecting marine species and habitats. Wave energy facilities could hinder fishing opportunities, supplant recreational activities, diminish aesthetic views, and create navigational hazards. The existence and extent of these potential impacts are, of course, site-specific, and so analyzing the possibilities in a framework such as CMSP is desirable.

Evaluating a site's capacity for wave energy depends on various factors, including wave power resources; the characteristics and costs of wave energy conversion devices; demand and pricing for electricity; availability of transmission networks; constraints on siting of energy conversion facilities; and compatibility with other uses or ecosystem attributes. Economic valuation of harvestable wave energy facilitates the evaluation of tradeoffs between locating a facility in a particular location for energy and the costs of installing, maintaining, and operating the facility at that location. Because technologies for wave energy production are still in the development stage, however, our focus is not on the magnitude of its economic value or even whether the value is positive or not. Instead, our intent is to find the best locations for wave energy facilities, given certain assumptions about the economic parameters that affect those locations. These locations are then compared to the spatial distribution of existing marine uses, which enables us to (crudely) identify areas where potential conflicts exist.

We use an existing GIS-based decision-support tool to provide spatially explicit information for evaluating wave energy conversion facilities and possible conflicts with other marine uses. The tool is the Wave Energy Model (WEM) of the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) toolkit (Tallis et al. 2011, Kim *et al.* forthcoming). The wave energy model consists of three parts: 1) assessment of potential wave power based on wave conditions; 2) quantification of harvestable energy using technology specific information about a wave energy conversion device; and 3) assessment of the economic value of a wave energy conversion facility over its life span as a capital investment. We apply this model to the siting of a potential wave energy facility along the coast of Oregon. (Our focus on Oregon is motivated by the availability of wave energy, power infrastructure, fishing, and other data specific to that state.) Below, we first discuss the application of the WEM, and then present the results of the wave energy facility analysis. Finally, we illustrate the potential for conflicts with other marine uses through a series of graphics.

METHODS AND DATA

WAVE ENERGY FACILITY LOCATIONS

Our analysis of wave energy production focuses on coastal Oregon, in an area defined by a north and south border (46° and 42°, respectively) and an east and west border defined by water depth (200m and 40m, respectively). The choice of water depths roughly bounds the range in which the wave energy device we chose (Pelamis) can operate (Pelamis Wave Power Ltd. 2010.). We configured a wave energy facility based on previous work by the Electric Power Research Institute (Previsic 2004b), which analyzed the system level design, performance, and cost of a commercial size offshore wave power plant installed off the coast of Oregon using the Pelamis device. Our configuration for an individual wave energy facility consists of four sets of 45 devices, the facilities arrayed in a north-south direction and creating a footprint 12 km long and 2 km wide. In the analysis below, we consider a set of three facilities, with each facility connected to the Bonneville Power Administration power grid at distinct locations along the Oregon coast.

As noted above, we used the InVEST WEM tool to analyze the potential electricity production and net economic value of this system of wave energy facilities. The WEM tool uses wave and water depth information to assess the potential energy that can be captured by wave energy devices. By choosing a particular device, the WEM tool can then quantify the captured wave energy and electricity production for particular locations. The economic value of energy production is estimated based on the economic costs (capital, operating, and maintenance) of the device and the transmission of the power. The location with the maximum net economic value is what we term the optimal location for the wave energy facility.

Specifically, the WEM tool uses the following input data:

- Water depth
- Wave height and power
- Performance and costs of specific wave energy conversion devices
- Electricity prices and discount rate
- Transmission line landing and power grid connection points

Table 1 lists the types and sources of data we used that are default choices for the WEM tool (version 2.2.2). For other data inputs, we chose particular values based on factors particular to Oregon or for other reasons, listed in Table 2.

Obtaining accurate input data and parameters for the economic valuation portion of the model is a significant challenge because there have been no commercial-scale wave energy facilities implemented to date. These economic parameters determine whether a wave energy facility will be economically viable – that is, whether the net present value of its construction, operation, and maintenance will be greater than zero. Of these economic parameters, however, only variation in the level of the underwater transmission line costs affects the optimal location of a wave energy facility, along with the choice of landing and power grid connection points. In our analysis, we considered three possible levels of transmission costs, which we describe as low cost, medium cost, and high cost scenarios (Table 2). Because the potential power grid connection points are largely determined by the current Bonneville Power Administration's transmission system, we use only one set of connection points (Table 2).

EXISTING MARINE USES

We considered three sets of existing marine uses and examined how they might conflict with the optimal locations of the wave energy facilities. The existing marine uses were 1) fishing; 2) transportation and utilities; and 3) marine conservation areas (Table 3).

For fishing, we used two sources of information to locate areas along the Oregon coast where fishing effort is present and how the value of fishing varies spatially. The first source (described in Appendix A) documents fishing effort along the coast of Oregon for three different commercial fleets, distinguished by gear type (bottom trawl, at-sea hake midwater trawl and fixed gear), that could be expected to occur within each of the nine proposed wave farm sites. Fishing effort was represented on either 10 km (bottom trawl fleet [herein trawl] and at-sea Pacific hake (*Merluccius productus*) midwater trawl [herein hake] fleet) or 20 km (fixed gear fleet [herein fixed]) grids. We used data from 2002 – 2009 that were provided by the At-sea Hake Observer Program (A-SHOP) and the West Coast Groundfish Observer Program (WCGOP) under NOAA's Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring (FRAM) Division.

Commercial fishing effort data are subject to restrictions that preserve confidentiality as required under the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006. As such, data cannot be presented to the general public unless it represents information from three or more vessels. Therefore, we ran all of our analyses using gridcells that represented the efforts of three or more vessels, and gridcells in the overlap maps that contained data from two or fewer vessels are not displayed.

The second source of information for fishing (Steinback et al. 2010) uses the results of fisherman surveys and, in some cases, harvest data to illustrate how the use and value of fisheries vary spatially.[1] Steinback et al. (2010) collected information from commercial, charter, and recreational fisheries for several Oregon ports (Table 4). The individual sector results were normalized and then aggregated for each

[1] Using electronic and paper nautical charts of the area, fishermen were asked to identify, by fishery, the maximum extent north, south, east, and west that they would forage or target a species. They were then asked to identify, within this maximum forage area, which areas are of critical economic importance, over their cumulative fishing experience, and to rank these using a weighted percentage—an imaginary "bag of 100 pennies" that they distribute over the fishing grounds. All maps based on Steinback et al. (2010) are considered "social" or stated importance maps, as they give equal weighting to each fishery in a sector and equal weighting to each sector when combined together. Port-level maps should not be combined with each other, and an overlap in fishing areas between maps should not be considered additive.

individual port. The results illustrate how the use and value of fishing effort in the aggregate varies spatially for a given port, but comparisons across ports are not possible.

For transportation, we considered two types of shipping corridors: 1) shipping lanes as recorded on NOAA's Electronic Navigation Charts (NOAA 2011b), and 2) lanes established for tug and barge traffic under on ongoing agreement between tug and barge operators and crab fisherman managed by the Washington Sea Grant (Washington Sea Grant 2010). For utilities, we considered submarine cables as recorded on NOAA's Electronic Navigation Charts (NOAA 2012), as these cables could conflict with the location of moorings for a wave energy facility.

Finally, we considered two types of marine conservation areas: 1) critical habitat designated under the Endangered Species Act (ESA), and 2) essential fish habitat conservation areas designated under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For critical habitat, designation of an area requires federal agencies or other parties with federal permits or licenses to avoid adversely modifying that habitat. Agencies that have activities or that issue such permits or licenses are required to consult with the National Marine Fisheries Service to ensure that these actions to not have such adverse effects. Critical habitat for green sturgeon (*Acipenser medirostris*) has been designated along the Oregon coast (as well as elsewhere along the Washington and California coasts), and so we considered that designation for our analysis (NOAA 2009). Essential fish habitat conservation areas have been designated for Pacific groundfish along the Oregon coast. These areas apply to several types of fishing gear and impose various types of constraints. For our analysis, the relevant areas are ones that prohibit fishing with bottom trawl gear (NOAA 2006).

RESULTS

Based on the wave energy facility configuration and the values in Tables 1 and 2 for the WEM InVEST tool, we identified three sets of optimal locations, depending on the cost scenario (Figure 1). Across all connection points, the optimal locations for an individual wave energy facility ranges between 13.1 and 70.4 kms offshore, with facility locations farther from shore when a lower transmission cost is assumed (Table 5). The average distance for the three facilities in each scenario is 16.1, 31.2, and 55.5 kms for the high, medium, and low cost scenario, respectively. The average energy captured per device also increases as lower transmission costs are assumed, which corresponds to the higher wave energy potential further offshore along the Oregon coast (Table 5). The total MwH/yr captured by all three facilities would be 3564, 3462, and 3324 MwH/yr for the low, medium, and high cost scenarios, respectively.

For fishing, the focus on particular fleets shows possible conflicts with the at-sea hake midwater trawl and bottom trawl fleets (Figures 2a and 2b). For the fixed gear groundfish fleet, the problem of missing data due to confidentiality restrictions limits any conclusions that can be drawn (Figure 2c). For the at-sea hake midwater and bottom trawl fleets combined, the medium cost scenario presents the strongest potential conflict in terms of a wave energy facility interfering with groundfish harvesting (Table 6).

Using the data on more general fishing location choices and values for specific ports, there is (unsurprisingly) a stronger possibility of conflict for ports that are close or the same as the points chosen for power grid connections (Figures 3a – 3g, esp. 3a and 3c). As has been noted, however, the methods used for constructing the underlying port-specific fishing datasets make comparisons across ports problematic. Nevertheless, in almost all cases, the potential for conflict with a particular port's fishing areas is strongest for the high cost scenario, in which wave energy facilities are closest to shore. An interesting exception is the port of Florence, where the potential for conflict is strongest for the low cost scenario due to a highly valued fishing area for that port that is relatively far from shore (Figure 3d).

For shipping and towing lanes, there is a strong potential conflict with the tugboat and barge tow lanes established off shore of all three connection points for the high cost scenario (Figure 4a), while conflicts with shipping lanes are less likely (Figure 4b). For submarine cables, there is a potential conflict with cables connected to the Tillamook area (Figure 4c). As noted above, however, the presence and extent of this conflict is speculative, as it can only be based on the mooring requirements for the wave energy device and not on the spatial location alone of the wave energy facility.

Finally, the locations of some wave energy facilities overlap green sturgeon critical habitat (Figure 5a), with each of the three facilities for the high cost scenario overlapping. This overlap could trigger requirements for federal agencies such as the Federal Energy Regulatory Commission to consult with NOAA Fisheries before licensing a wave energy facility. For the Pacific groundfish conservation areas, there is an overlap for two of the three low cost scenario facilities. Because these areas are currently managed as closures to harvest for certain groundfish fleets, the exact nature of any potential conflict is uncertain.

DISCUSSION

Using an existing GIS-based tool for evaluating potential locations of wave energy facilities, we have demonstrated how potential conflicts with existing marine uses can be identified. The variety of methods used by various data sources to measure the intensity and value of these uses makes a comparison across uses or an aggregation of the conflicts problematic. Nevertheless, a simple set of spatial representations can present planners with a screening tool, identifying areas where a more refined investigation is worthwhile.

The InVEST WEM tool has the capability of quantifying the consequences, in terms of captured wave energy and economic value, of moving the wave energy facilities to alternate locations, changing the land connection points, and so forth. Coupled with similar quantitative measures of the change in a facility's impact on existing marine uses, this capability would allow for an extended assessment of the potential tradeoffs between wave energy production and those other uses. This would provide an important analysis for CMSP.

Several deficits prevent us from exploring this issue, however. As noted above, the data sources for the existing marine uses are limited in how they spatially measure the intensity and value of those uses. (None of the existing uses are assessed in terms of economic value.) While some conclusions can be drawn for a particular use that certain locations are likely to create "more" or "less" of a conflict, little more than that can be said. Second, for some uses, a conflict or lack of one is inferred from the presence or absence of that use in a particular location. Much more must be understood about the real nature of conflicts and the ability of various uses, including wave energy production, to coexist spatially before a viable tradeoff analysis could be conducted. And finally, many of the other uses can choose alternate locations in response to a spatial conflict. An understanding of how such choices are made and the availability and value of alternate locations would be needed, again, for a robust tradeoff analysis.

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APPENDIX A

PACIFIC GROUNDFISH HARVEST EFFORT FOR THREE FISHING FLEETS

METHODS

We overlaid two different geospatial data layer types for these analyses: potential wave farm sites and cumulative observed groundfish fishery effort. We quantified the amount of fishing effort by three different commercial fleets by gear type (bottom trawl, at-sea hake midwater trawl and fixed gear) that could be expected to occur within each of the nine proposed wave farm sites.

GROUNDFISH FISHERY DATA

Fishing effort was represented on either 10 km (bottom trawl fleet [herein trawl] and at-sea Pacific hake (*Merluccius productus*) midwater trawl [herein hake] fleet) or 20 km (fixed gear fleet [herein fixed]) grids. We used data from 2002 – 2009 that were provided by the At-sea Hake Observer Program (A-SHOP) and the West Coast Groundfish Observer Program (WCGOP) under NOAA's Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring (FRAM) Division.

Commercial fishing effort data are subject to restrictions that preserve confidentiality as required under the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006. As such, data cannot be presented to the general public unless it represents information from three or more vessels. Therefore, we ran all of our analyses using gridcells that represented the efforts of three or more vessels, and gridcells in the overlap maps that contained data from two or fewer vessels are not displayed.

At-sea hake midwater trawl fishing effort was collected directly by the A-SHOP (National Oceanic and Atmospheric Administration (NOAA) 2011). The A-SHOP collects information on total catch (fish discarded and retained) from all vessels that process Pacific hake at-sea. All data were collected according to standard protocols and data quality control established by the ASHOP (National Oceanic and Atmospheric Administration (NOAA) 2011).

Bottom trawl fishing effort (National Oceanic and Atmospheric Administration (NOAA) 2010) was derived from fleet-wide logbook data submitted by state agencies to the Pacific Fisheries Information Network (PacFIN) regional database, maintained by the Pacific States Marine Fisheries Commission (PSMFC). A common-format logbook is used by Washington, Oregon, and California. Trawl logbook data are regularly used in analyses of the bottom trawl groundfish fishery observed by the WCGOP.

For both the trawl and hake spatial data, a trawl towline model (line drawn from the start to end location of a trawl tow) was used to allocate data to the 10 x 10 km grid cells for calculation of cumulative fishing effort (hours that gear was deployed in the water).

Fixed gear fishing effort was expressed as the cumulative number of sets, as opposed to the time gear was in the water. These data were collected directly by the WCGOP from the following commercial groundfish fixed gear sectors: limited entry sablefish primary (target – sablefish), limited entry non-sablefish endorsed (target – sablefish/groundfish), open access fixed gear (target – groundfish), and Oregon and California state-permitted nearshore fixed gear (target – nearshore groundfish). Both the observed fixed gear set (start location of fishing) and haul (location of gear retrieval) were assigned to 20 x 20 km grid cells for calculation.

The fishing effort associated with each fixed gear fishing event was divided equally between the set and haul locations.

For the hake and trawl fleets, the data represents total fishing effort (100%). All at-sea hake vessels (catcher-processors and motherships) over 125 feet are required to carry two observers, while vessels under 125 feet carry one. PacFIN fleet-wide logbook data are assumed to represent the entire bottom trawl fleet for our analysis. However, all fishing operations may not necessarily be recorded in logbooks and logbook submission may not be complete. Observer data did not capture 100% of the fishing effort for the fixed gear fleet, so we calculated the proportion (C) of the fleet that was represented by the observer data:

$$C = \sum_{s=1}^{5} \left(\frac{t_s}{T} \times \frac{w_{s(obs)}}{W_{s(land)}} \right)$$

s corresponded to each of the five sectors, t was the total time (in hours) a given sector was observed with gear in the water, T was the total time (in hours) all five of the sectors were observed with gear in the water, w was the total retained weight of target fish species caught on vessels with observers present (reported by sector) and W was the total landed weight of target fish species by all vessels (reported by sector).

Catch data are reported on an annual basis, so we ran the calculation across all years (2002-2009) by multiplying the data reported for each sector by the proportion that that sector represented over the entire study area. The observed portion of overall fixed gear effort varied by coverage level in each sector (Table 1). Since all fishing operations were not observed, neither the maps nor the data can be used to characterize the fishery completely.

OVERLAP WITH GROUNDFISH FISHERY

We used ESRI ArcGIS (v. 9.3) to run our spatial analyses. We calculated the expected cumulative fishing effort for each of the nine proposed wave farm sites by intersecting the rectangular polygons representing each site with each of the three different commercial fishing fleet grids. Using the attribute information from the intersected polygons, we converted cumulative fishing effort (hours/10 km gridcell for the at-sea hake and bottom trawl fleets; sets/20 km gridcell for the fixed gear fleet) to cumulative effort per km^2. We then multiplied the effort per unit area by the total area for each proposed wave farm (30 km^2), which yielded an estimate of the cumulative effort for each wave farm site.

Table 1. InVEST WEM data input default values

Category	Item	Source
Water depth	Water depth [m]	Amante and Eakins (2009)
Wave power	Wave height [m]	NOAA (2011c)
	Peak wave period [sec]	
Wave energy device performance	Captured wave energy for a given seastate condition defined by wave height and wave period [kW]	Previsic (2004a)
	Maximum capacity of device [kW]	
	Upper limit of wave height for device operation [m]	
	Upper limit of wave period for device operation [sec]	
Wave energy device costs	Capital cost per installed kW [$/kW].	Dunnett and Wallace (2009)
	Cost of mooring lines [$ per m]	
	Cost of overland transmission line [$ per km]	
	Operating & maintenance cost [$ per kWh]	

Table 2. InVEST WEM data input choices

Data Input	Description
Area of Interest	North and south boundaries set at 46 degrees and 42 degrees. East and west boundaries determined by water depth, 40 and 200 meters respectively.
Wave energy device	Pelamis
Wave energy facility	4 cluster of 45 devices
Cost of underwater transmission line [$ per km]	We chose three levels of cost: Low cost scenario = $100,000 per km Medium cost scenario = $250,000 per km High cost scenario = $500,000 per km Based on figures from Dunnett and Wallace (2009).
Landing and power grid connection	Tillamook, Toledo, and Tahkentich substations, Bonneville Power Administration, Transmission Asset Network. We chose these power grid connection points (and associated landing points) based on substation transformer capacity, not including any costs of upgrading local infrastructure to accommodate wave energy production. Source: Bonneville Power Administration (2012)
Price of electricity [$ per kWh]	5¢ / kWh. Source: U.S. Energy Information Administration (2011)
Discount rate	5%

Table 3. Existing marine uses

Marine Use	Activity Considered	Source
Fishing	Fishing effort for at-sea hake midwater trawl, bottom trawl and fixed gear, fishing effort (cumulative hours fishing by 10km cell, 2002-09)	See Appendix A
	Fisheries Uses and Values, selected Oregon ports	Steinback et al. (2010)
Transportation	Shipping lanes	NOAA (2011b)
	Crabber-Tugboat tow lanes	Washington Sea Grant (2010)
Utilities	Submarine cables	NOAA (2012)
Conservation areas	Green sturgeon critical habitat	NOAA (2009)
	Pacific groundfish Essential Fish Habitat conservation areas	NOAA (2006)

Table 4. Fisheries uses and values (Steinback et al. 2010)

Port Group	Commercial	Charter	Recreational
Garibaldi	Dungeness Crab-Trap, Salmon–Troll, Rockfish–Fixed Gear, Shelf Bottom Trawl	N/A	Dungeness Crab, Pacific Halibut, Rockfish, Salmon
Depoe Bay	Dungeness Crab-Trap, Salmon–Troll, Rockfish–Fixed Gear, Urchin-Dive	Dungeness Crab, Pacific Halibut, Rockfish, Salmon	Dungeness Crab, Pacific Halibut, Rockfish, Salmon
Newport	Dungeness Crab-Trap, Salmon–Troll, Rockfish–Fixed Gear, Shelf Bottom Trawl	Dungeness Crab, Pacific Halibut, Rockfish, Salmon	Dungeness Crab, Flatfish, Pacific Halibut, Rockfish, Salmon
Florence	Dungeness Crab-Trap, Salmon-Troll	Dungeness Crab, Pacific Halibut, Rockfish, Salmon	Dungeness Crab, Pacific Halibut, Rockfish, Salmon
SOORC (Charleston, Coos Bay, Bandon, Winchester Bay, Reedsport)	Dungeness Crab-Trap, Salmon–Troll, Rockfish–Fixed Gear, Shelf Bottom Trawl	Dungeness Crab, Pacific Halibut, Rockfish, Salmon	Dungeness Crab, Pacific Halibut, Rockfish, Salmon
Port Orford	Dungeness Crab-Trap, Salmon–Troll, Rockfish–Fixed Gear, Urchin-Dive	N/A	N/A
Gold Beach/Brookings	Dungeness Crab-Trap, Salmon–Troll, Rockfish–Fixed Gear, Urchin-Dive	Dungeness Crab, Pacific Halibut, Rockfish, Salmon	Dungeness Crab, Pacific Halibut, Rockfish, Salmon

Table 5. Optimal wave energy facilities

Cost scenario	Power Grid Connection Point	Distance of facility from landing point (km)	Average energy captured per device (kWh/yr)
Low	Tillamook	58.6	2,198
	Toldeo	37.4	2,181
	Tahkenitch	70.4	2,221
Medium	Tillamook	23.5	2,126
	Toldeo	33.6	2,165
	Tahkenitch	36.5	2,121
High	Tillamook	13.1	2,076
	Toldeo	16.4	2,061
	Tahkenitch	18.8	2,019

Table 6. Potential groundfish-wave energy conflicts

		Cumulative Duration 2002-2009 (hrs/km²)			Cumulative Sets 2002-2009 (no./km²)
Cost Scenario	**Power Grid Connection Point**	**Bottom trawl**	**At-sea hake**	**Trawl + hake**	**Fixed gear**
Low	Tillamook	0.30	conf.	0.30	0.11
	Toldeo	1.65	conf.	1.65	0.18
	Tahkenitch	0.72	0.45	1.17	0.11
Medium	Tillamook	1.28	0.23	1.51	conf.
	Toldeo	3.77	0.43	4.20	0.20
	Tahkenitch	1.80	0.52	2.32	conf.
High	Tillamook	1.01	conf.	1.01	0.36
	Toldeo	1.01	conf.	1.01	0.00
	Tahkenitch	0.32	conf.	0.32	conf.

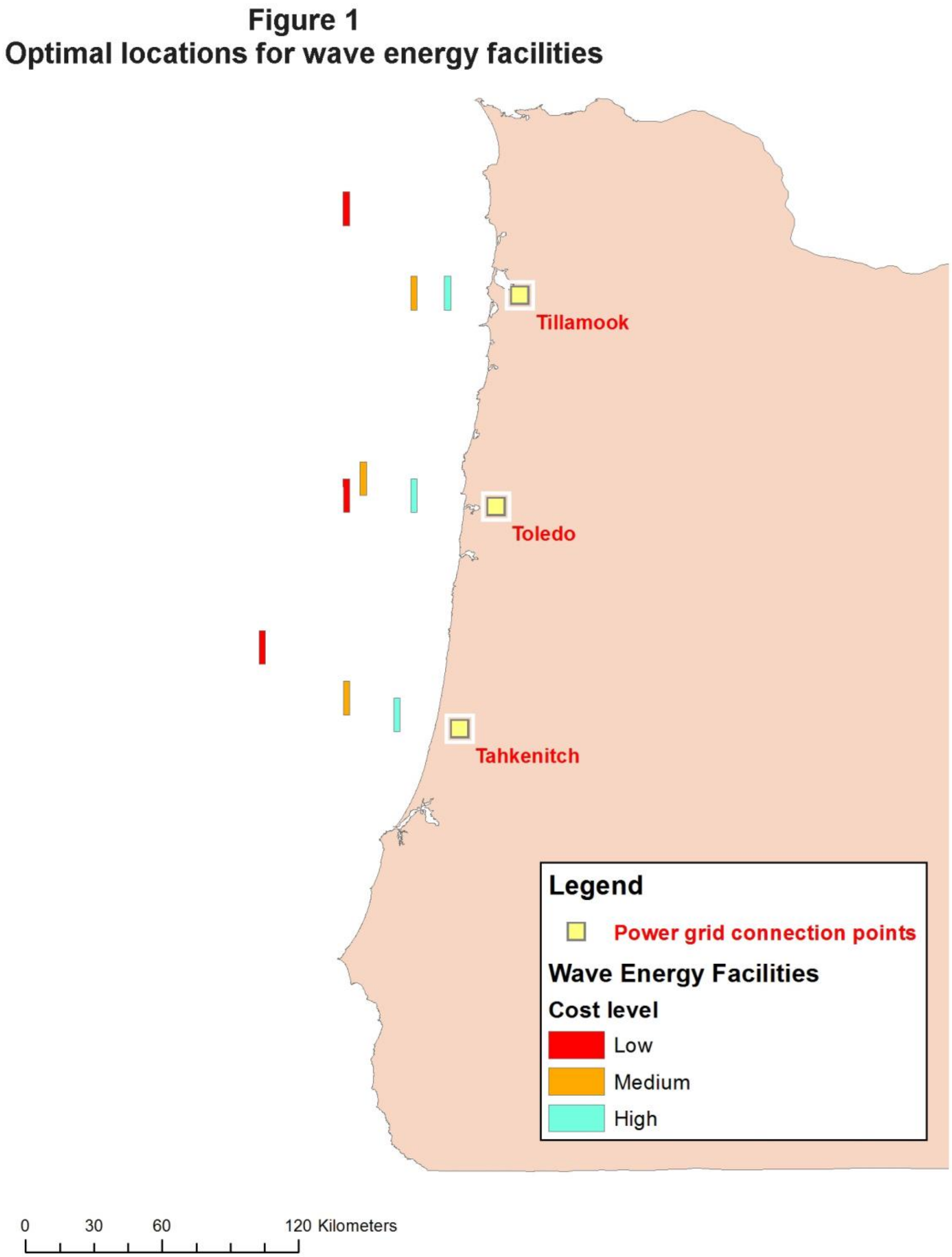
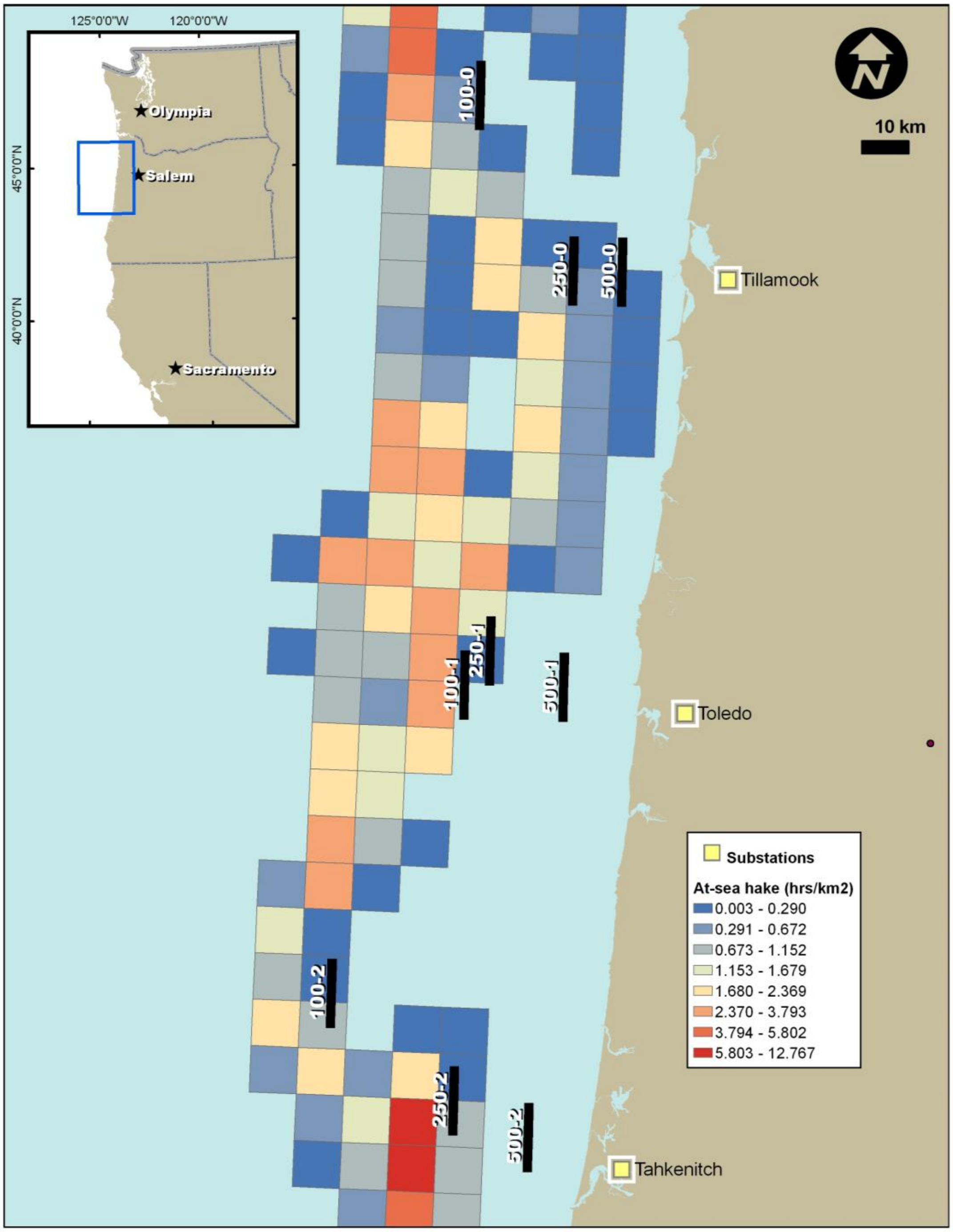


Figure 1: Using the Wave Energy Model InVEST tool, we identified three sets of optimal locations, depending on the cost scenario. The location with the maximum net economic value is what we term the optimal location for the wave energy facility.

Figure2a
Groundfish at-sea hake fishing effort



Figures 2a - 2c: We used data from 2002 - 2009 to document fishing effort along the coast of Oregon for three different commercial fleets, distinguished by gear type (bottom trawl, at-sea hake midwater trawl, and fixed gear), that could be expected to occur within each of the proposed wave farm sites. These data reveal possible conflicts with the at-sea hake midwater trawl (2a) and bottom trawl fleets (2b), while for the fixed gear groundfish fleet, the problem of missing data due to confidentiality restrictions limits any conclusions that can be drawn (2c).

Figure2b
Groundfish bottom trawl fishing effort

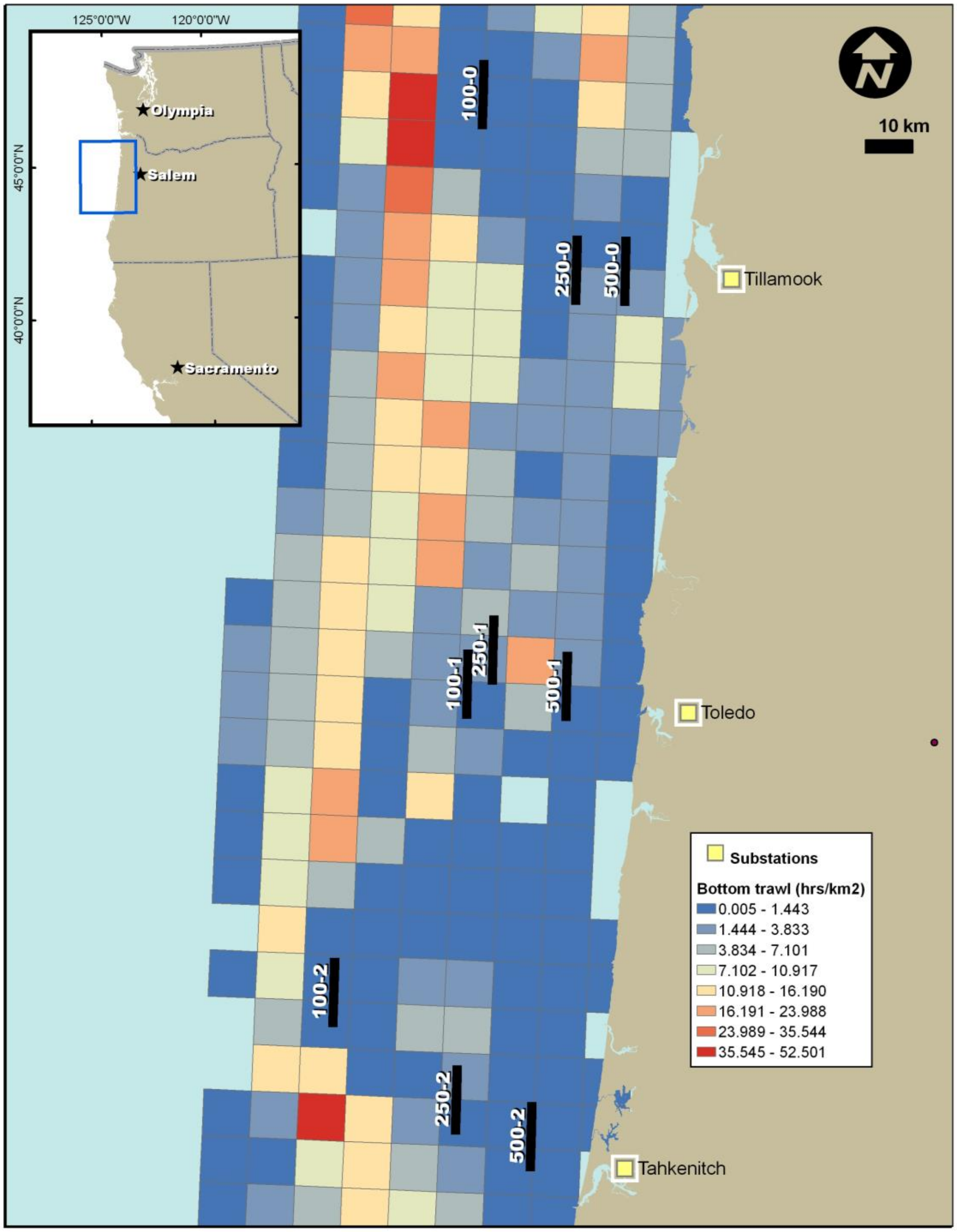
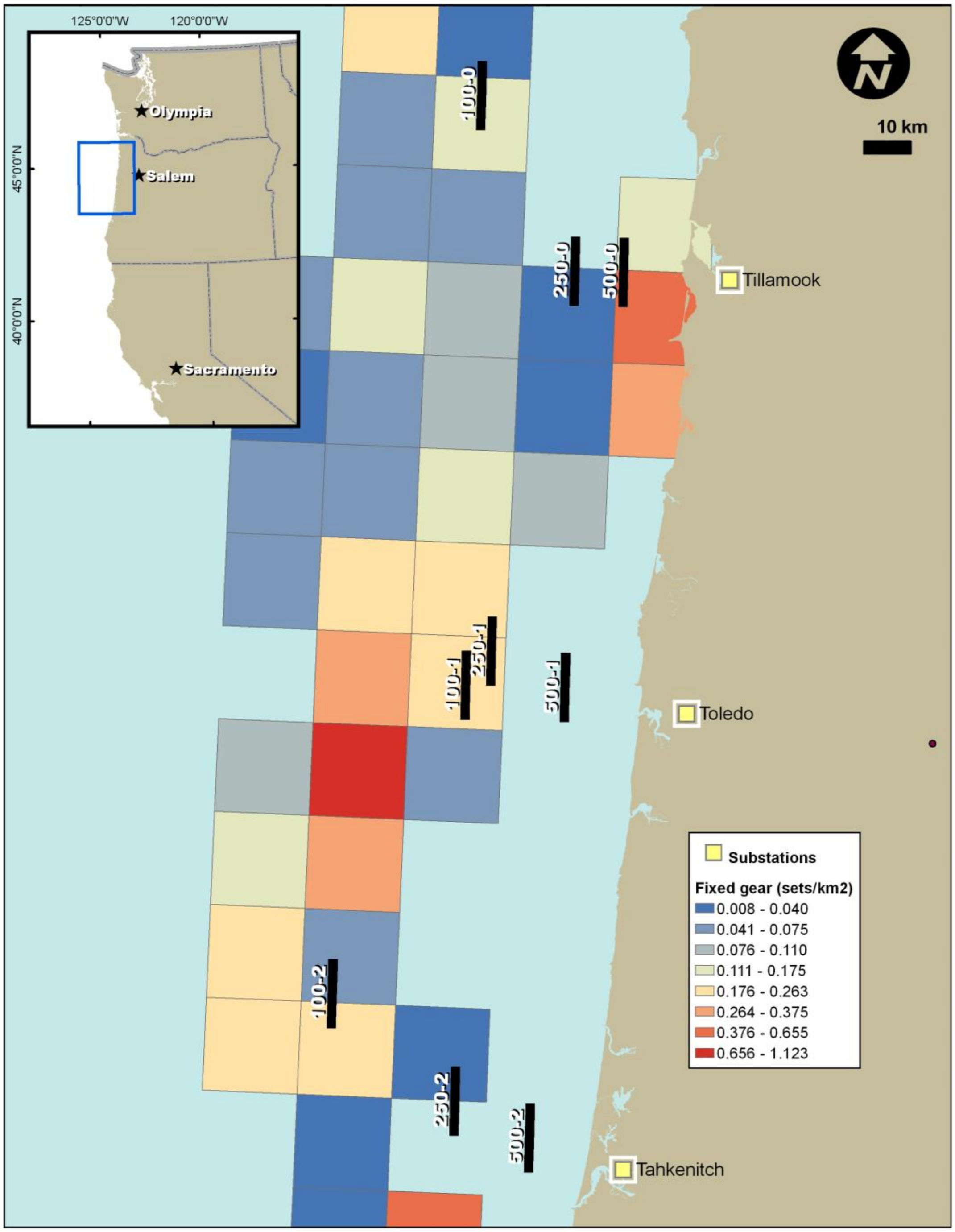


Figure2c
Groundfish fixed gear fishing effort



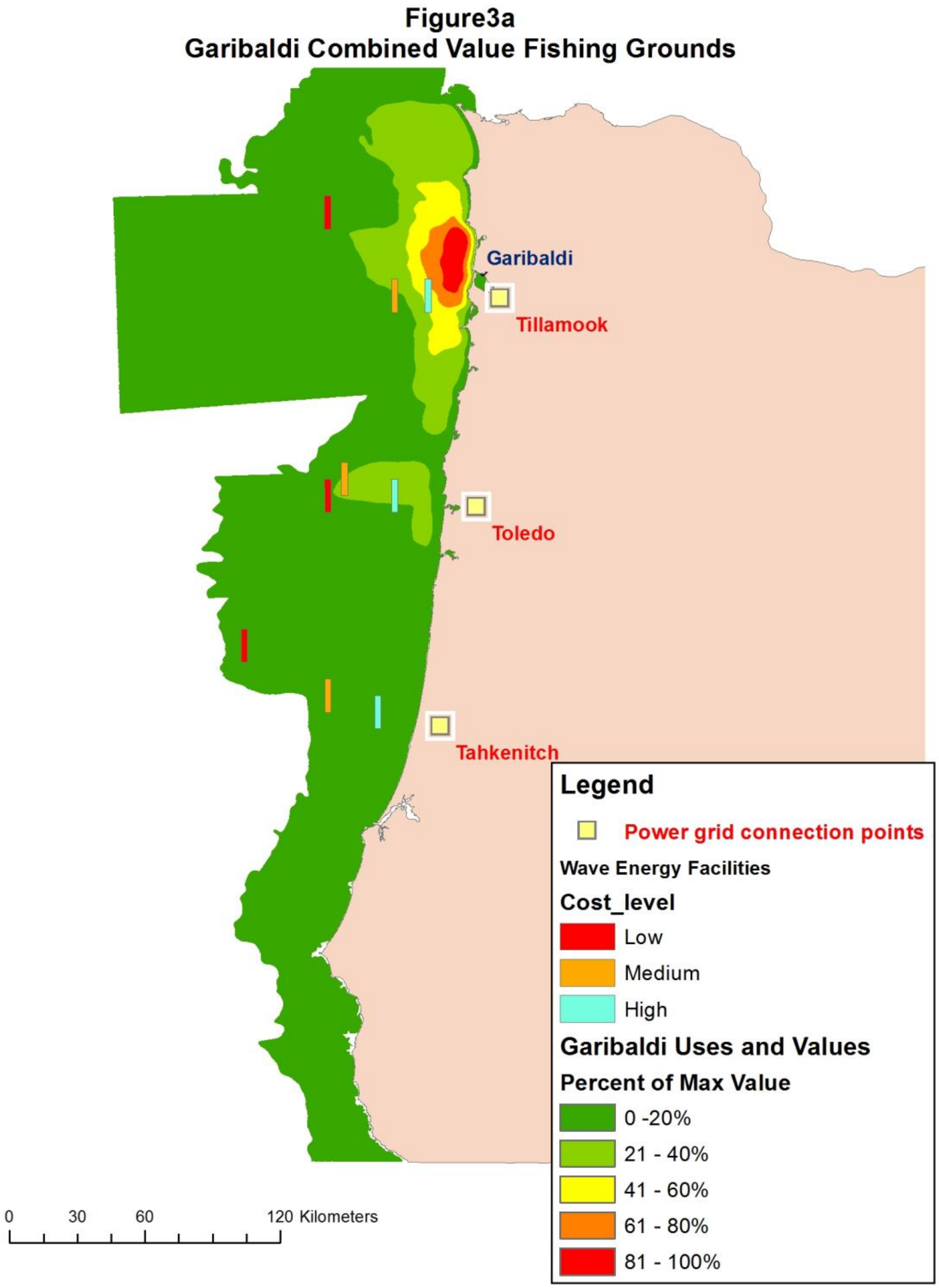


Figure 3a - 3g: Using data collected by Steinback et al. (2010) from commercial, charter, and recreational fisheries for several Oregon ports, there is a stronger possibility of conflict for ports that are close or the same as the points chosen for power grid connections (3a - 3g).

Figure3b
Depoe Bay Combined Value Fishing Grounds

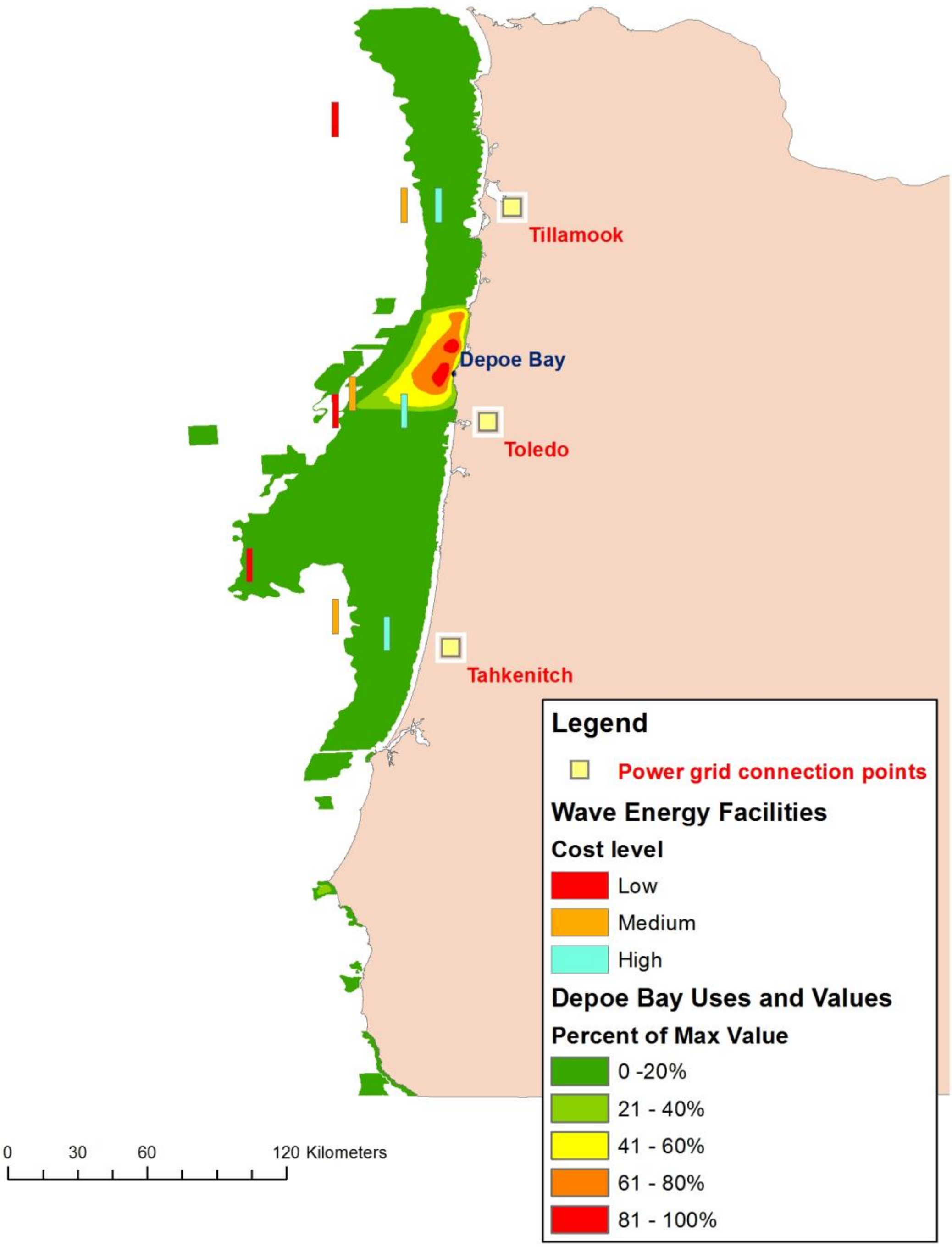
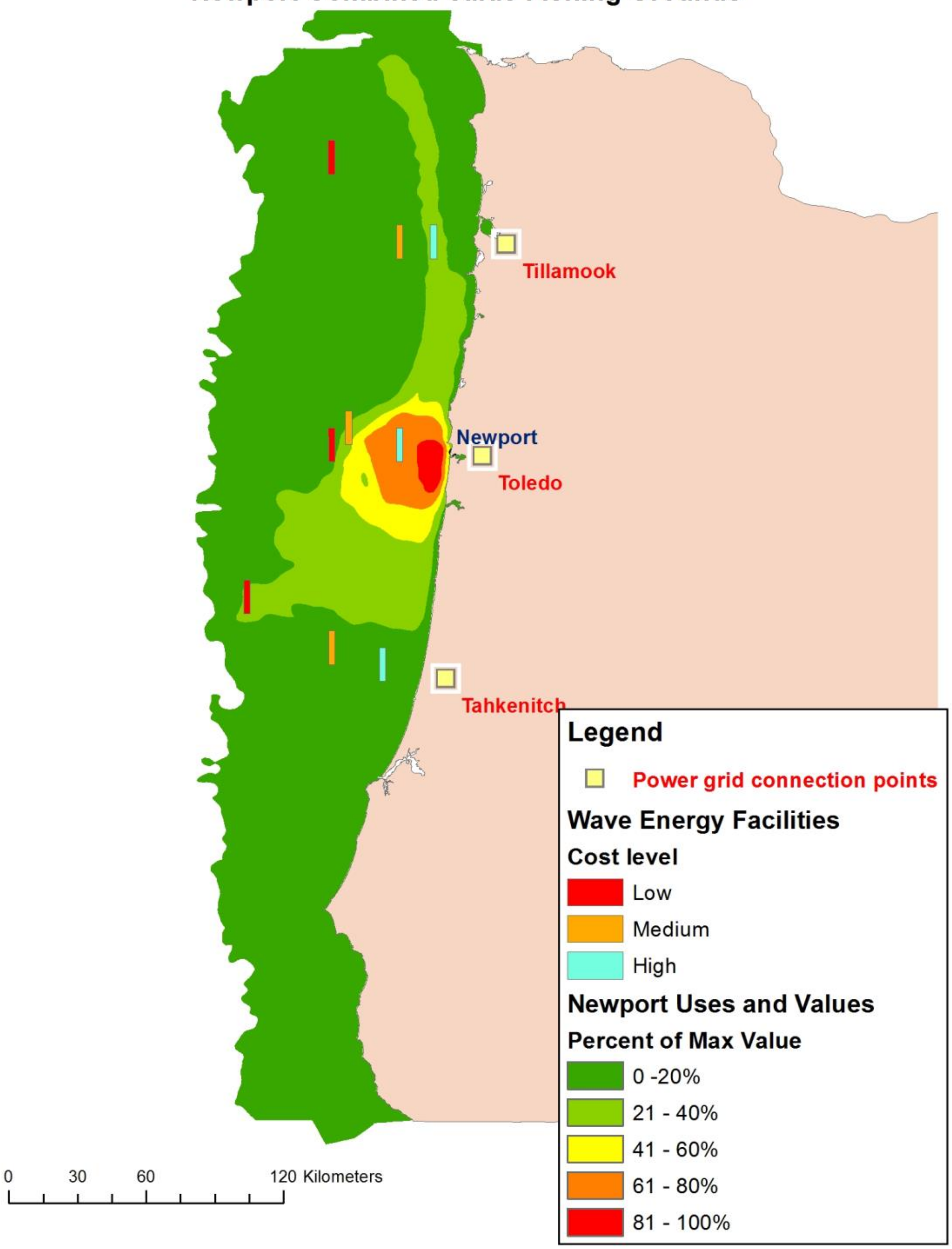


Figure3c
Newport Combined Value Fishing Grounds



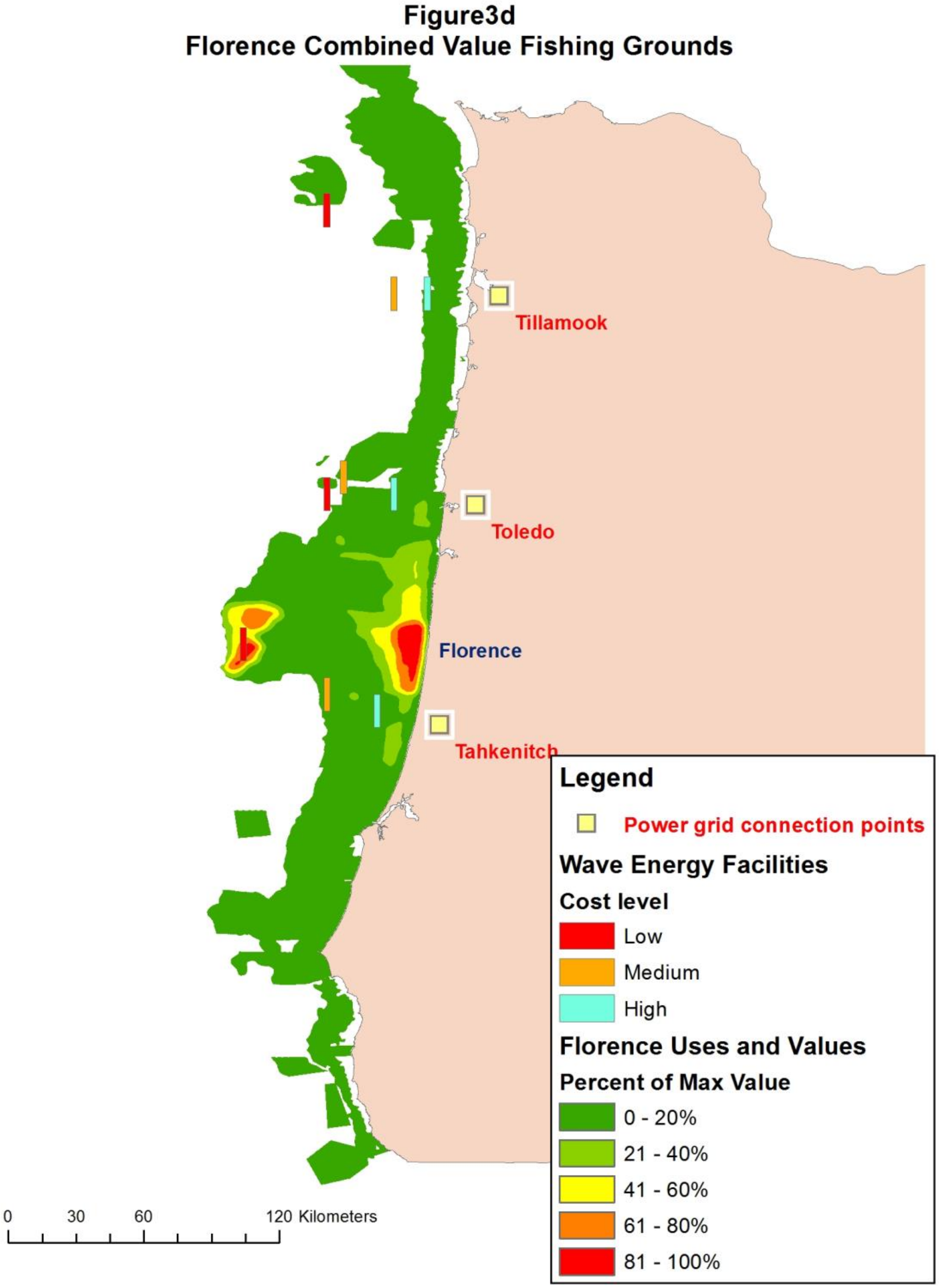


Figure3d
Florence Combined Value Fishing Grounds
Tillamook
Toledo
Florence
Tahkenitch
0
30
60
120 Kilometers
Legend
Power grid connection points
Wave Energy Facilities
Cost level
Low
Medium
High
Florence Uses and Values
Percent of Max Value
0 - 20%
21 - 40%
41 - 60%
61 - 80%
81 - 100%

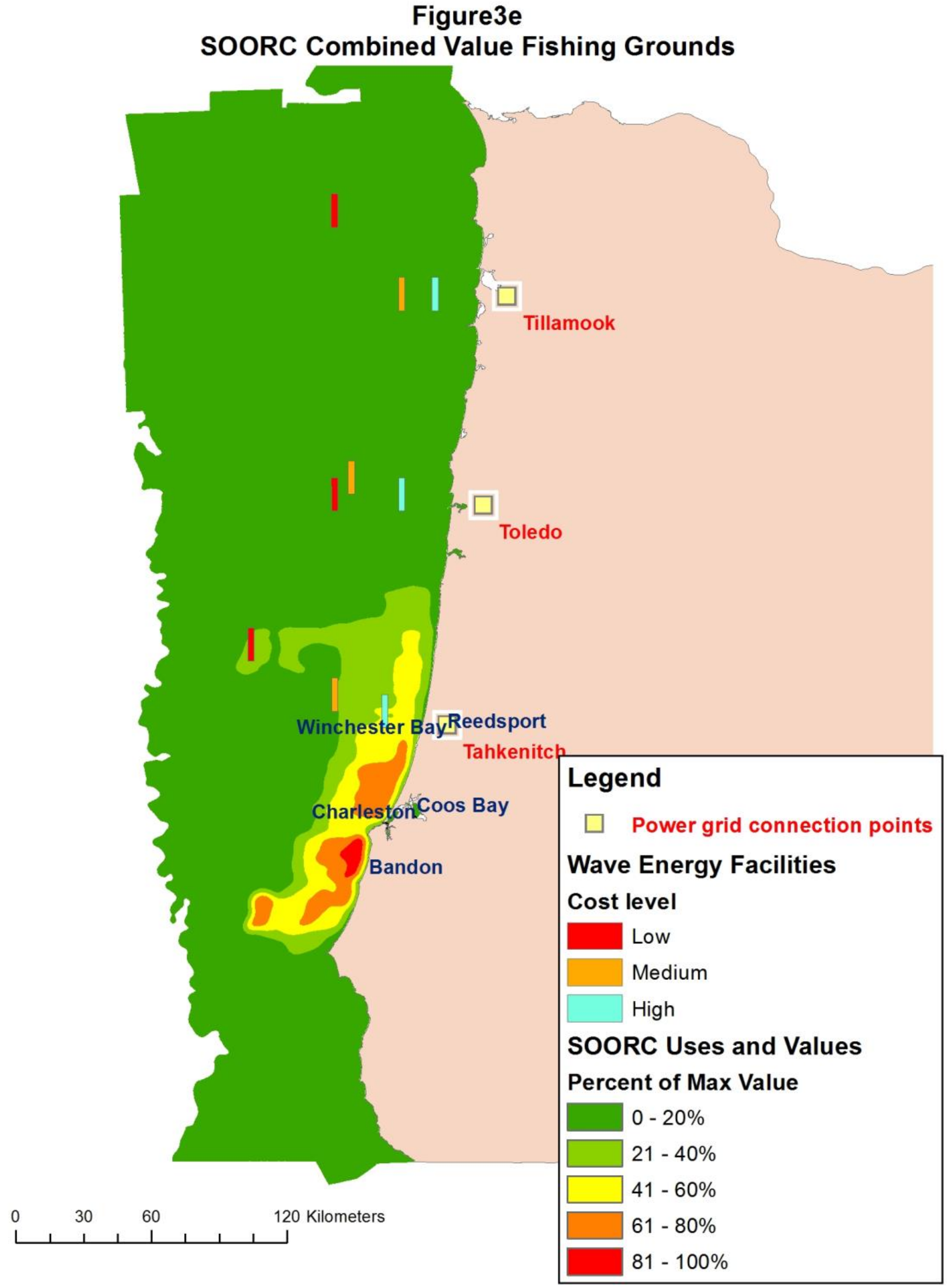


Figure3e
SOORC Combined Value Fishing Grounds
Tillamook
Toledo
Winchester Bay
Reedsport
Tahkenitch
Charleston
Coos Bay
Bandon
0
30
60
120 Kilometers
Legend
Power grid connection points
Wave Energy Facilities
Cost level
Low
Medium
High
SOORC Uses and Values
Percent of Max Value
0 - 20%
21 - 40%
41 - 60%
61 - 80%
81 - 100%

Figure3f
Port Orford Combined Value Fishing Grounds

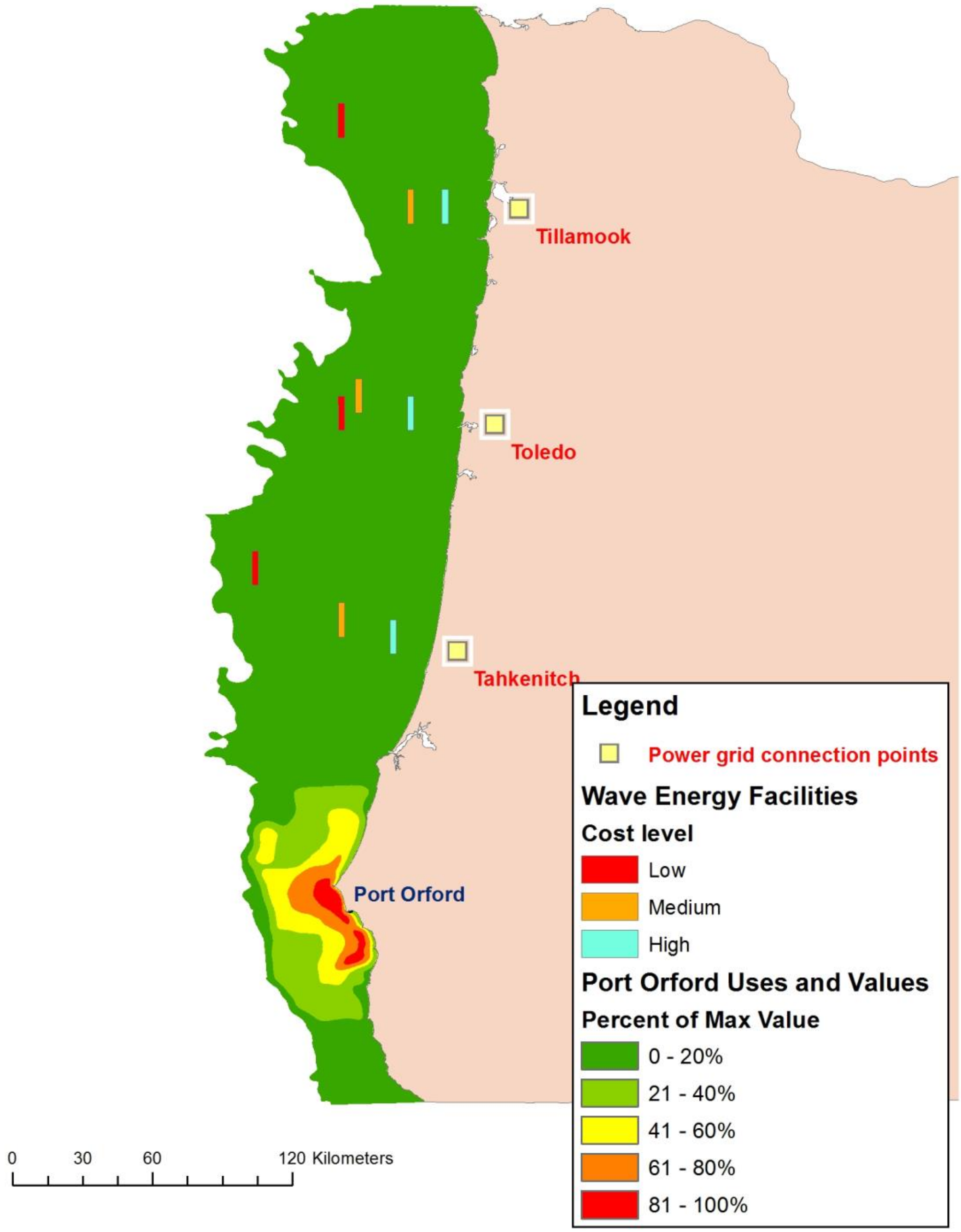
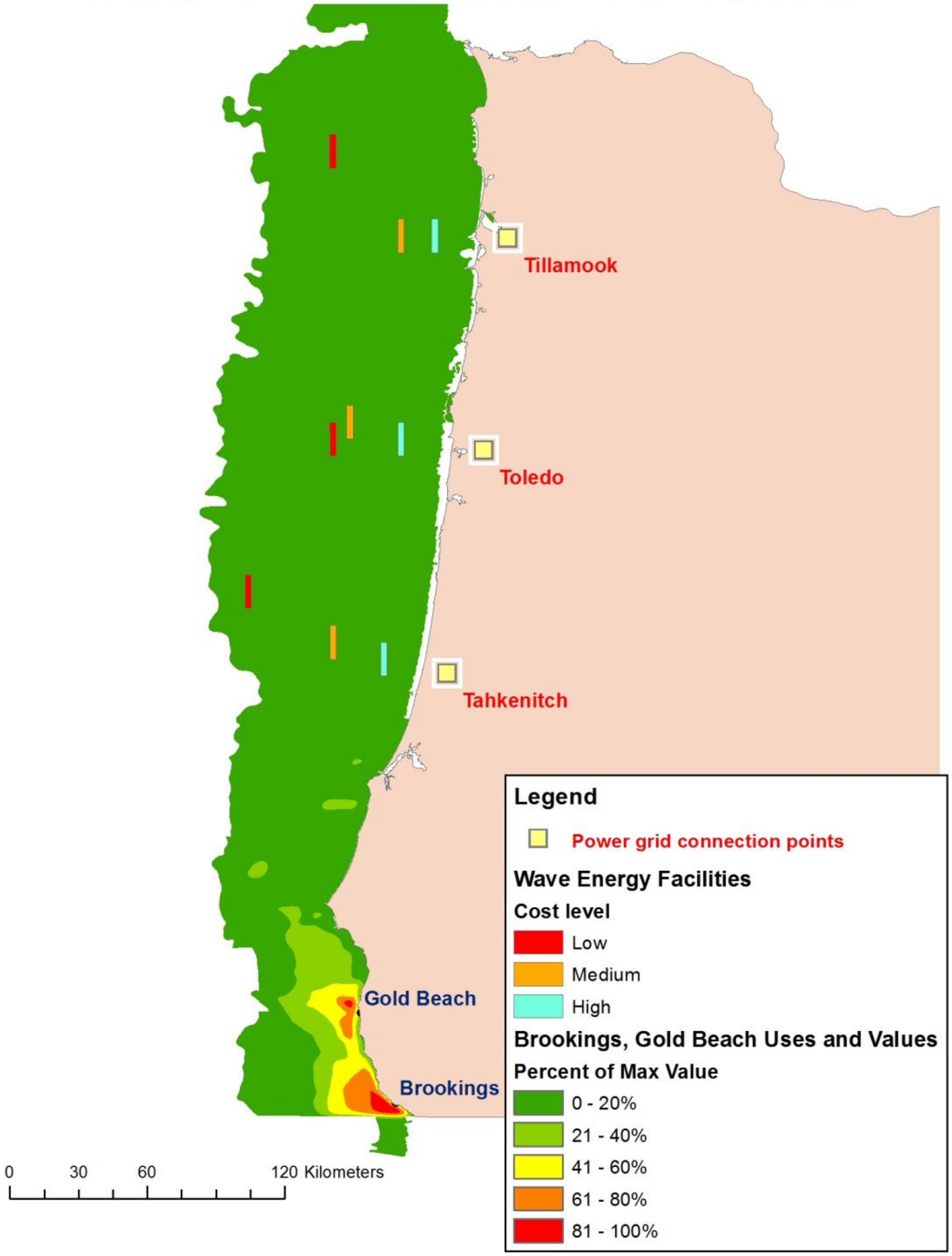


Figure3g
Brookings and Gold Beach Combined Value Fishing Grounds



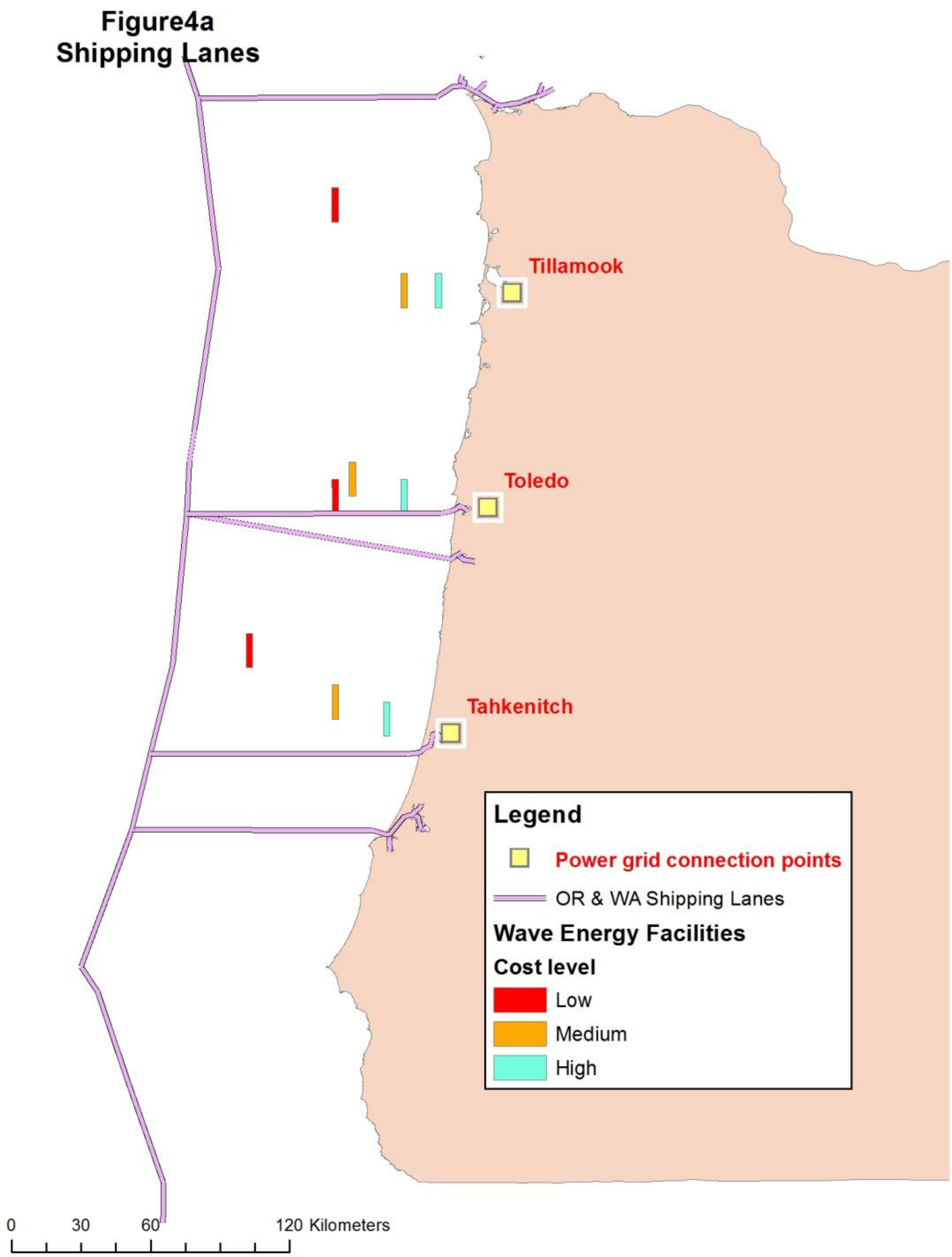


Figure 4a - 4c: For shipping lanes (4a) and towing lanes (4b), there is a strong potential conflict with the tugboat and barge tow lanes established off shore of all three connection points for the high cost scenario, while conflicts with shipping lanes are less likely. For submarine cables, there is a potential conflict with cables connected to the Tillamook area (4c).

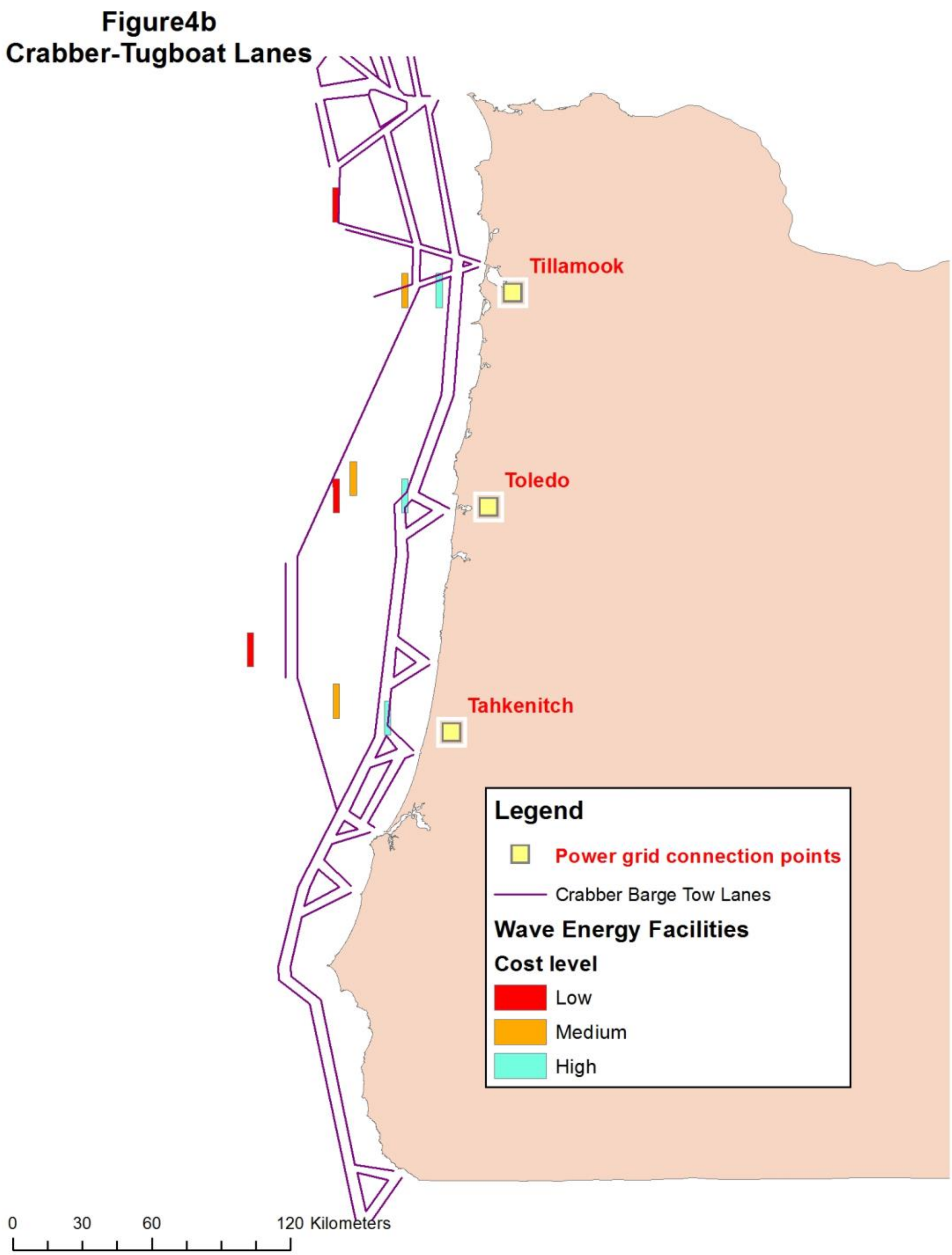


Figure4b
Crabber-Tugboat Lanes
Tillamook
Toledo
Tahkenitch
Legend
Power grid connection points
Crabber Barge Tow Lanes
Wave Energy Facilities
Cost level
Low
Medium
High
0
30
60
120 Kilometers

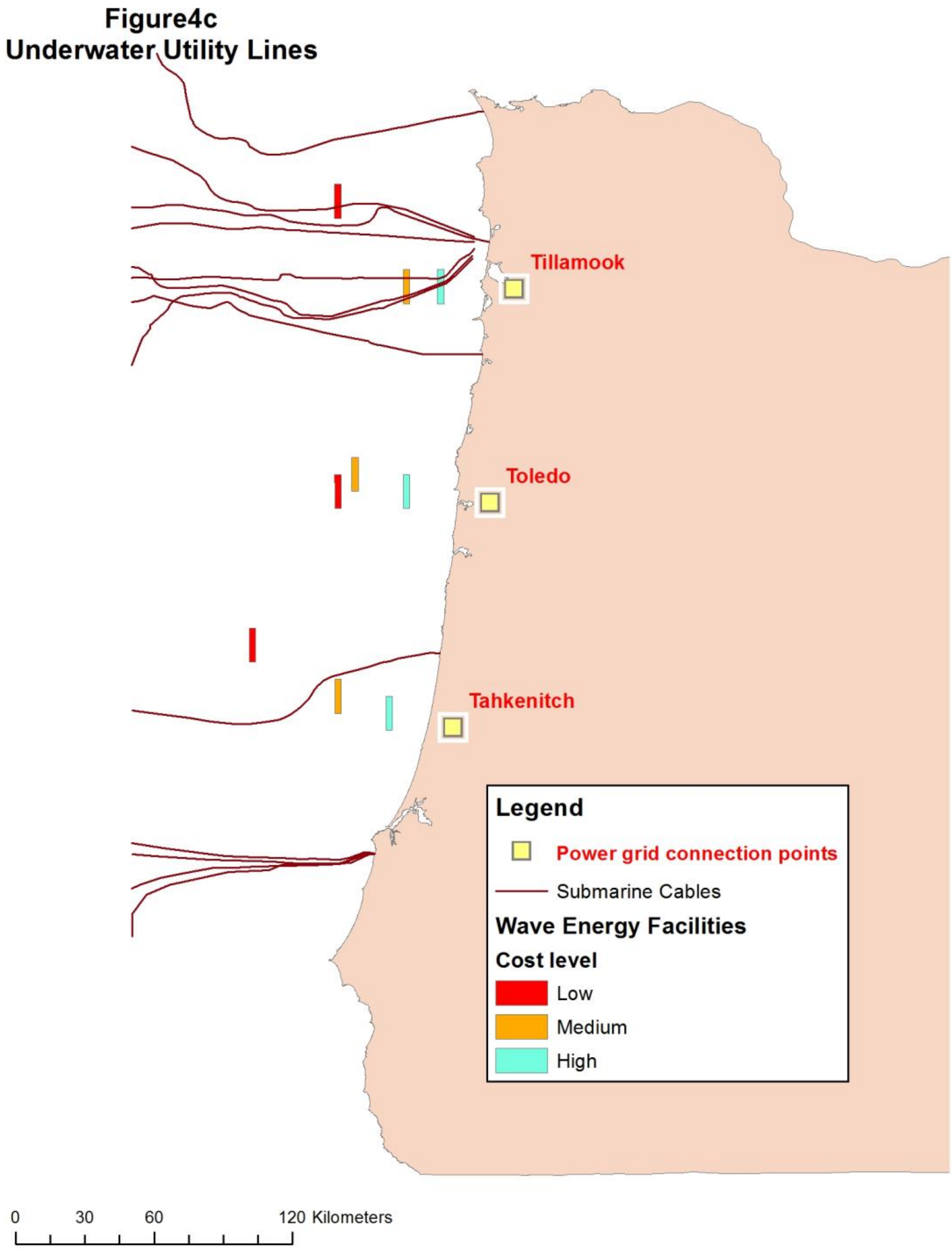


Figure4c
Underwater Utility Lines
Tillamook
Toledo
Tahkenitch
Legend
Power grid connection points
Submarine Cables
Wave Energy Facilities
Cost level
Low
Medium
High
0 30 60 120 Kilometers

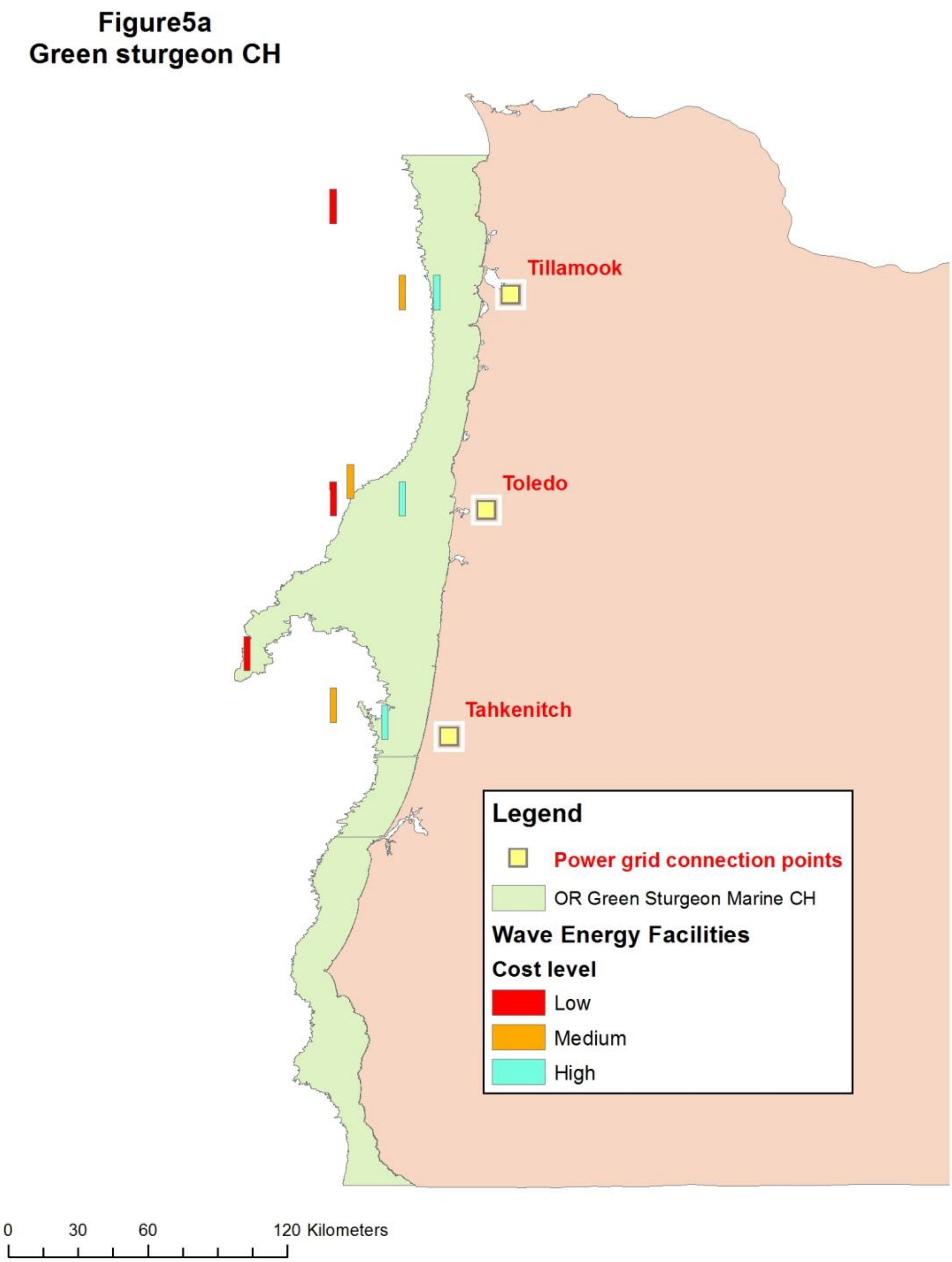


Figure 5a - 5b: The locations of some wave energy facilities overlap green sturgeon critical habitat designated under the Endangered Species Act (5a), which could trigger requirements for federal agencies such as the Federal Energy Regulatory Commission to consult with NOAA Fisheries before licensing a wave energy facility. For the Pacific groundfish conservation areas (5b), there is an overlap for two of the three low cost scenario facilities, but because these areas are currently managed as closures to harvest for certain groundfish fleets, the exact nature of any potential conflict is uncertain.

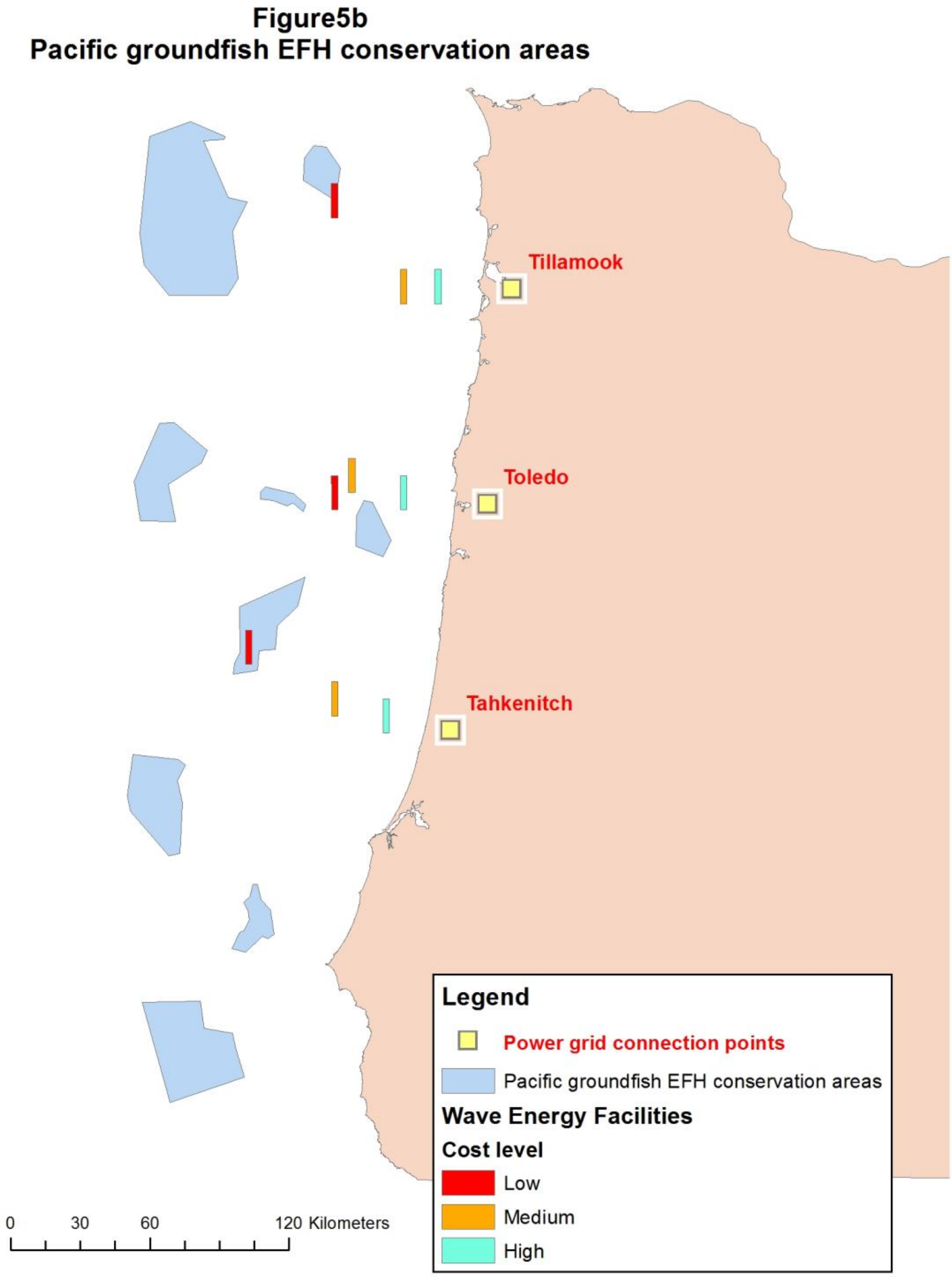


Figure5b
Pacific groundfish EFH conservation areas
Tillamook
Toledo
Tahkenitch
Legend
Power grid connection points
Pacific groundfish EFH conservation areas
Wave Energy Facilities
Cost level
Low
Medium
High
0
30
60
120 Kilometers

Table A1. Fixed gear fishing effort represented in West Coast Groundfish Observer Program (WCGOP) data by sector observed; including the proportion of total observed effort (cumulative hours gear was deployed) by sector from 2002-2009, the observed sector coverage rate calculated as the observed retained catch weight of target species divided by the fleet-wide landed weight of target species, and the assumed proportion of total fleet-wide effort represented in the observed data.

Sector (2002-2009)	**% of Total Duration by Sector**	**Sector Coverage Rate**	**Proportion of Duration Represented**
Limited Entry Sablefish Primary	59.38%	26.12%	15.51%
Limited Entry Non-Tier-Endorsed Fixed Gear	17.00%	7.41%	1.26%
Open Access Fixed Gear	18.63%	3.00%	0.56%
Oregon Nearshore Fixed Gear	3.83%	5.20%	0.20%
California Nearshore Fixed Gear	1.16%	3.43%	0.04%
Sum total percentage of duration represented = 17.57%			